Space Weather Technical Forecast

Issued on Tuesday 24 December 2024 at 01:29 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: Further R1/R2 radio blackouts expected. Chance of G1/Minor Geomagnetic Storms 25-26 Dec.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Moderate with three M-class flares observed. A peak flare reached M8.9 levels at 23/1112 UTC from AR3932 in the southeast.

There are currently twelve sunspot regions on the visible disc. The southeast quadrant remains the focus of solar activity, containing a cluster of the three largest and most complex regions (AR3928, AR3932 and AR3933). Slow development of all regions were observed during the period with a potential delta spot forming in the southern portion of AR3932. AR3935 and AR3937 in the southeast were numbered, as was AR3936 in the northeast, separated from nearby AR3934. A small, unnumbered region developed in the southwest disc. Other remaining regions were relatively small, stable and more magnetically simple. A new region was seen rotating onto the facing-disc in the far northeast, but is not yet unnumbered.

A moderately-fast CME associated with the M8.9 solar flare and sympathetic filament eruption was modelled as an expected, flanking impact on 25 Dec, or perhaps early 26 Dec. Otherwise a number of other CMEs have been observed in available imagery during the period, but analysis of these suggests none have an Earth-directed component.

Solar Wind / Geomagnetic Activity: Solar winds, observed at L1 by DSCOVR and ACE were elevated to strong, varying between 525-630km/s. Density was average to below average. The Interplanetary Magnetic Field (IMF), Bt, was initially moderate, but eased to become weak from around 23/0800 UTC. The north-south component, Bz, varied weakly throughout, ranging between +7 and -7nT, with no single direction predominant. Geomagnetic activity was Quiet to Unsettled (Kp1-3).

Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV) was well below the S1/Minor Storm threshold, but slightly elevated above normal background levels, on a slowly declining trend. High energy electron flux (greater than 2MeV) observed by GOES16 varied between moderate and high levels, with a peak of 1540pfu observed at 23/1725UTC. The associated 24-hour fluence was below the Active (1e8 integrated flux) threshold throughout. The 24/0000UTC observation was 4.32e7 integrated pfu, with a slow, rising trend.

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Four-Day Space Weather Forecast Summary

Solar Activity: Further M-class flares are expected, with a slight chance of isolated X-class flares maintained throughout.

Solar Wind / Geomagnetic Activity: A CME that left the Sun late 20 Dec has a chance to give Earth a glancing impact early on Day 1 (24 Dec). A moderately-fast CME on 23 Dec from a flare and subsequent filament eruption in the southeast disc is expected to result in a flanking impact on Day 2 (25 Dec), or perhaps arriving early Day 3 (26 Dec). No other potential Earth-directed CMEs feature in the forecast, however, due to the sheer number of CMEs in evidence in solar imagery over the past several days, this means confidence in this aspect of the forecast is lower than usual.

An ongoing enhancement to the fast-wind of a coronal hole, giving elevated wind speeds, is expected to continue until Day 2 (25 Dec) before slowly declining. Further connection to a coronal hole in the northwest disc is possible from Day 3 (26 Dec) onwards, but considered unlikely given its high-latitude location.

Geomagnetic activity is expected to be mainly Unsettled on Day 1 (24 Dec) with isolated Active intervals likely and very slight chance of peak G1/Minor Storm conditions. On Day 2 and 3 (25 and 26 Dec), dependent on any CME arrival, peak Active to G1/Minor Storm levels are expected, with a slight chance of G2/Moderate Storm intervals. By Day 4 (27 Dec), mainly Quiet to Unsettled activity is forecast, but with a chance of Active periods, especially at first.

Energetic Particles / Solar Radiation: There is a slight chance of S1-level or greater enhancements during the period, increasing to a chance on Day 4 (27 Dec). In the absence of any further notable flares, ongoing slightly enhanced high-energy Proton counts should ease towards normal background levels in the coming days.

The high energy electron forecast carries lower-than-average confidence due to inherited uncertainties from the geomagnetic forecast, especially surrounding any potential glancing CME influence between Days 1-3 (24-26 Dec). Overall, the chance of exceeding the Active (1e8 integrated) threshold is greater than usual, with the main risk of exceeding occurring between Days 2 and 3 (25 and 26 Dec).

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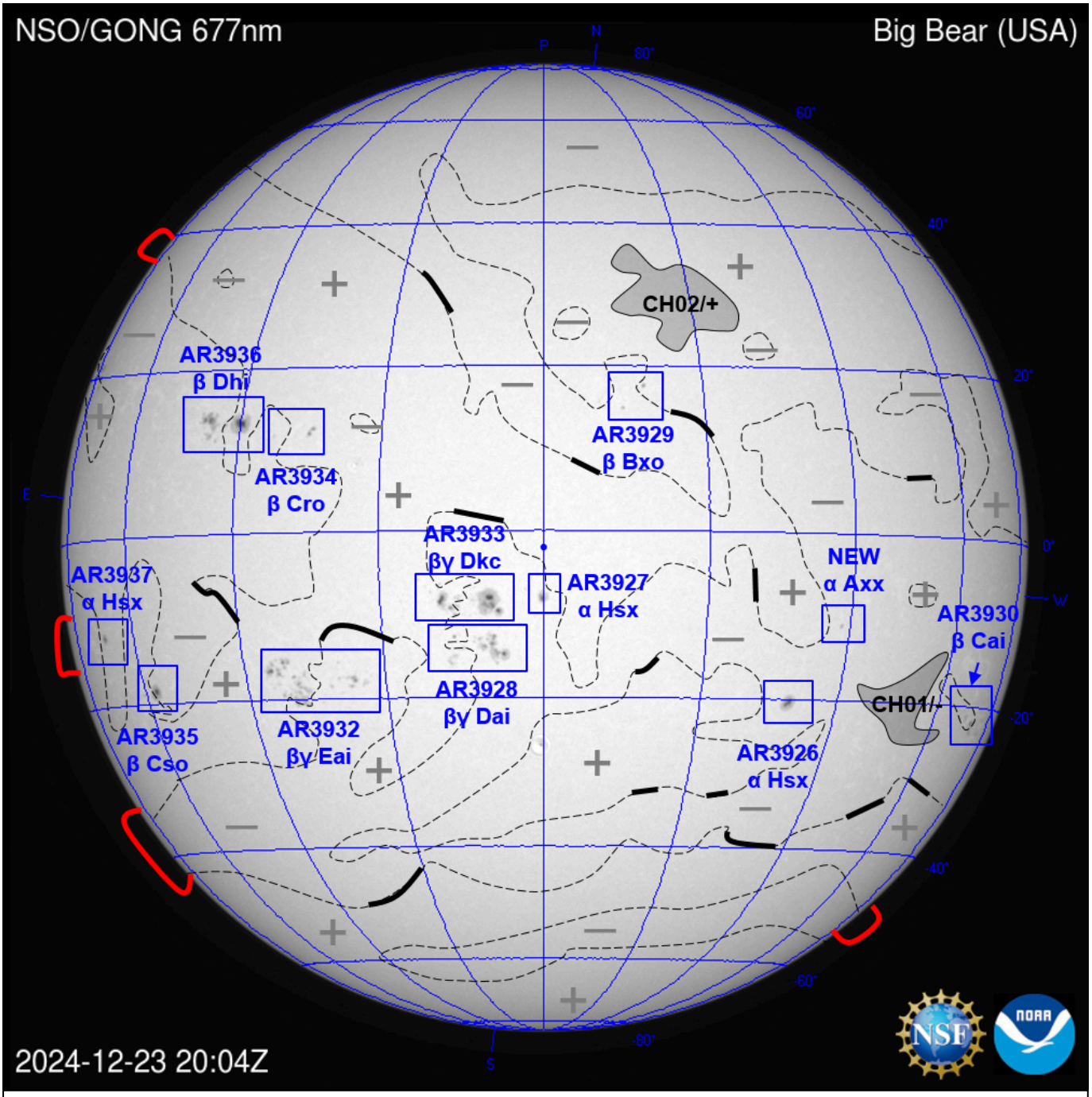
Figure 1: MOSWOC Solar Synoptic Map valid 23/2000 UTC



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms

A filament lift-off from the northeast disc late 20 Dec was modelled and gives a possible peripheral glance early on Day 1 (24 Dec). On 23 Dec a M8.9 flare from AR3923 and a nearby, sympathetic filament lift-off in the southeast disc resulted in a moderately-fast CME. Although the bulk of the ejecta is modelled to pass below the Earth-Sun line, a flanking impact is considered likely on Day 2 (25 Dec), with a chance of a delayed arrival early Day 3 (26 Dec). No other potential Earth-directed CMEs feature in the forecast, however, due to the sheer number of CMEs in evidence in solar imagery over the past several days, this means confidence in this aspect of the forecast is lower than usual.

Solar winds are Elevated due to ongoing connection to CH01/-. Influence from this feature is expected to persist through Days 1-2 (24-25 Dec), before declining, though this decline may be masked by anticipated CME influence, indicated above. A further enhancement is possible, but unlikely on Days 3 and 4 (26 and 27 Dec) from CH02/+ located in the northwest disc. This feature is non-recurrent and also may be located at too high a latitude on the disc to connect with Earth, reducing confidence in any impacts, though these would likely be minor should any enhancement occur.

Geomagnetic activity is expected to be mainly Unsettled on Day 1 (24 Dec) with isolated Active intervals likely and very slight chance of peak G1/Minor Storm conditions. On Day 2 and 3 (25 and 26 Dec), dependent on any CME arrival, peak Active to G1/Minor Storm levels are expected, with a slight chance of G2/Moderate Storm intervals. By Day 4 (27 Dec), mainly Quiet to Unsettled activity is forecast, but with a chance of Active periods, especially at first.

Geomagnetic Storm	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Minor or Moderate	G1 to G2	No	10	50	50	5
Strong	G3	No	1	10	10	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

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Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R⊙ (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed (km/s)	Estimated Arrival Time (UTC)	Comments
21/0535 UTC	Partial	Filament	NE quadrant	532	24/0000 UTC	Possible glance. Low confidence.
23/1550 UTC	Partial	Flare and Filament	SE disc (AR3932)	780	25/1800 UTC	Likely flanking impact. Moderate confidence on timings. +/- 9 hours from Estimated Arrival Time.

Figure 2: Latest MOSWOC Enlil output for 25/1800 UTC, estimated arrival time of CME from 23 Dec at Earth.

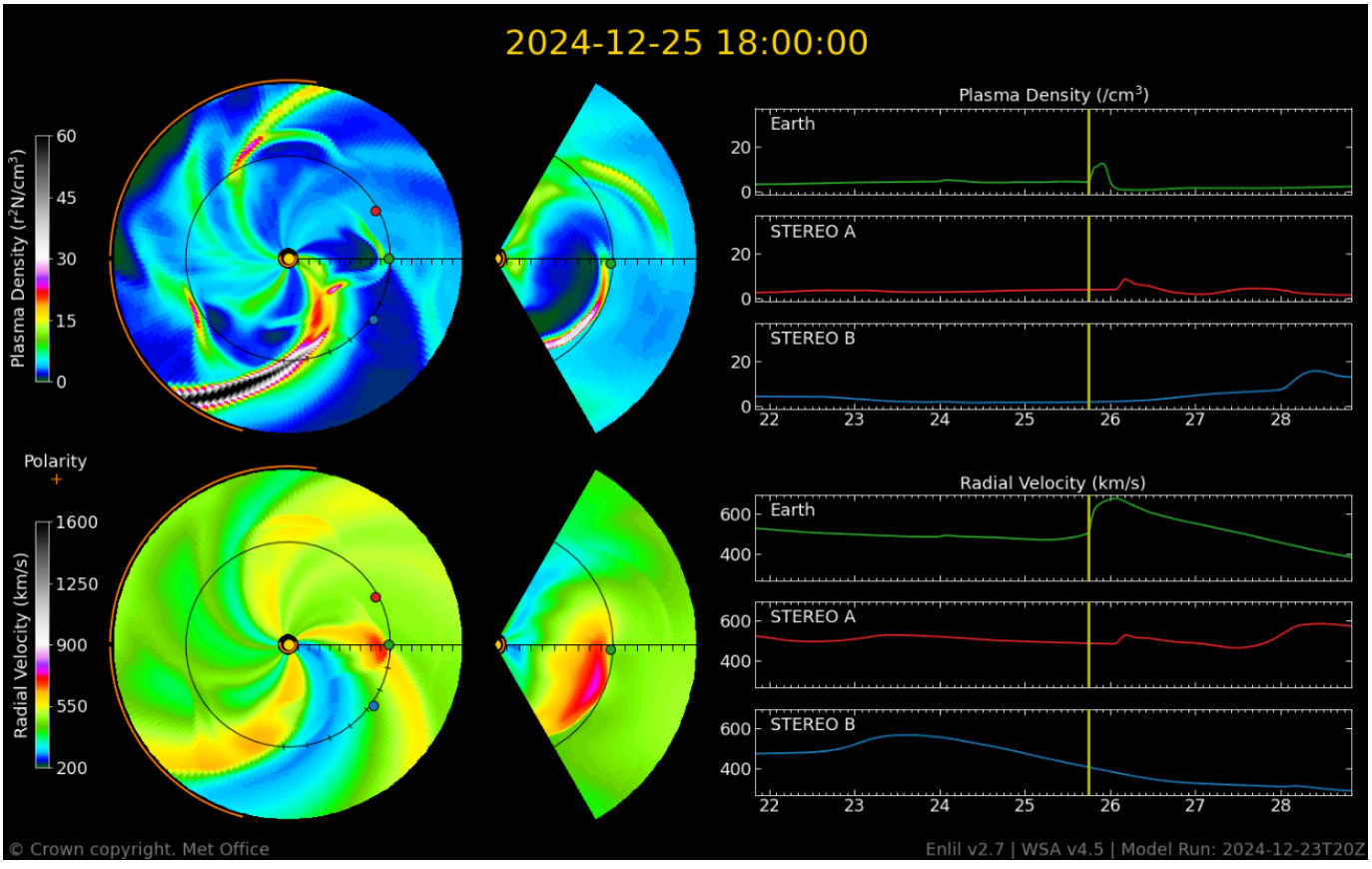

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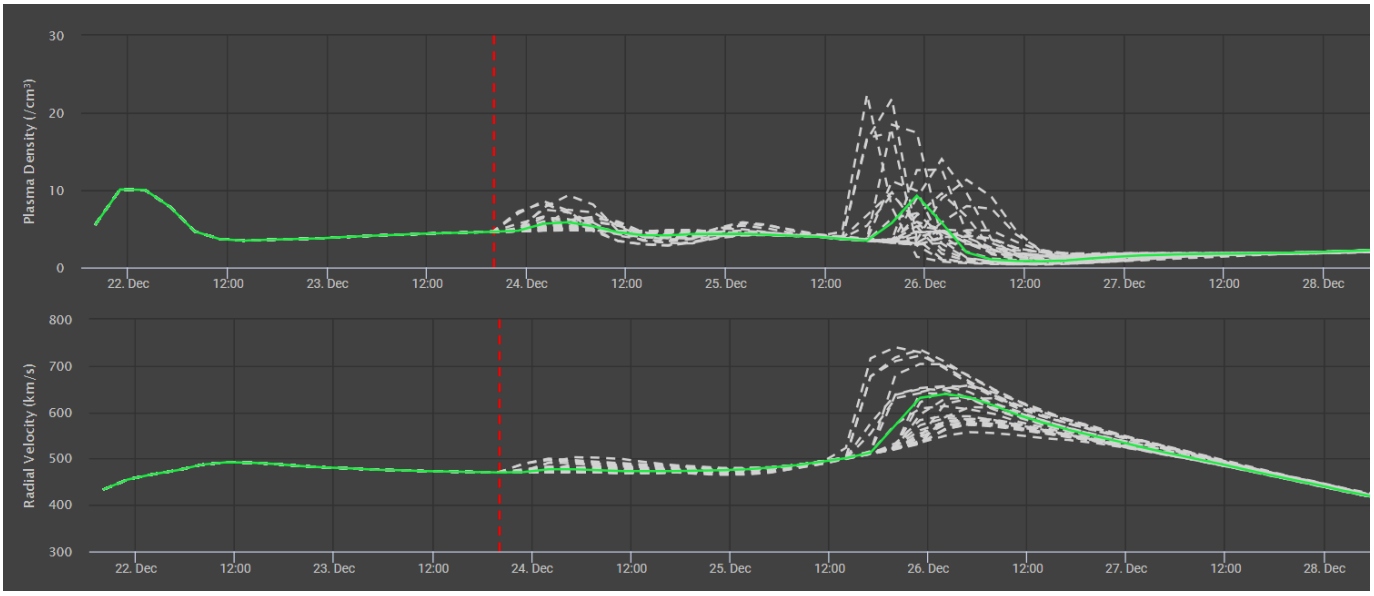
Figure 3: Latest MOSWOC Enlil ensemble output.



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Radio Blackouts - X-Ray Flares

Solar activity is at Moderate levels with observed background flux continuing to rise. A peak flare measured at M8.9 was observed from AR3932 at 23/1112 UTC. There are currently twelve sunspot regions on the visible disc, including one unnumbered group. The southeast quadrant remains the focus of solar activity, containing a cluster of the three largest regions (AR3928, AR3932 and AR3933). These are moderately large bipolar spot groups and show some degree of magnetic complexity and areal growth. AR3932 may also contain a small delta spot in its southern region, although a lack of high-resolution imagery from GONG makes confirmation of this challenging at this time. Other remaining sunspot groups on the disc are relatively small, stable and more magnetically simple.

A new region containing numerous spots is rotating over the northeast horizon, with significant magnetic looping present in SUVI imagery. This may present a risk of notable flares in the forecast period. Another region, likely returning Ex-AR3912, is expected on the visible disc from Day 1 (24 Dec). It previously was responsible for X-class flare activity earlier in December and was also likely the source of a large far-sided CME on 17 Dec. If the sunspot has maintained its complexity it could contribute to higher flare probabilities in the upcoming days.

The assessment of any new regions notwithstanding, flare risk looks to remain elevated during the period and further M-class flares are expected, with a slight chance of X-class flares maintained throughout.

X-Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 (M Class)	Yes	80	80	80	80
Very Active	R3-R5 (X Class)	No	15	15	15	15

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Figure 4: Latest GOES16/18 X-Ray flux trace.

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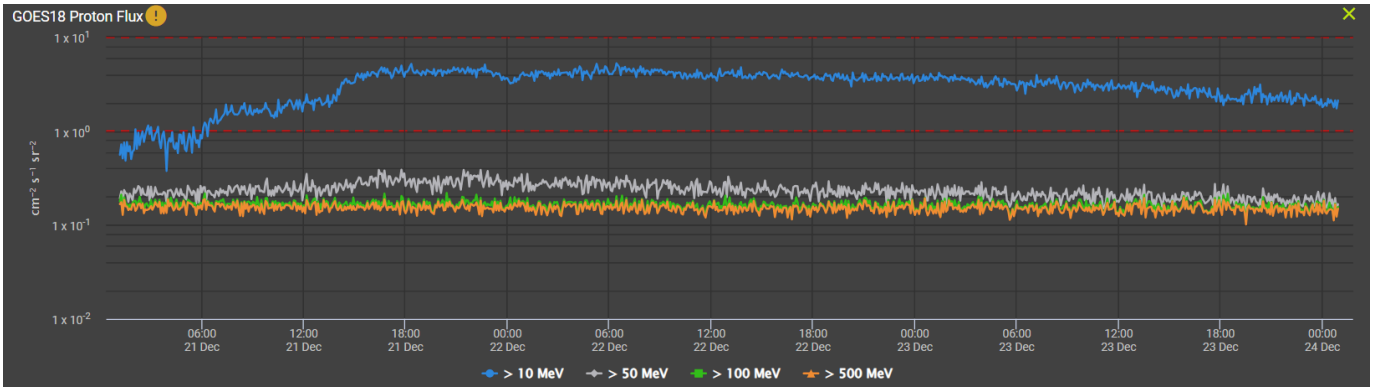
Solar Radiation Storms (High Energy Protons)

The source of the currently observed slight enhancement in the near-Earth environment is somewhat uncertain, but a far-sided source on 19 Dec seems most likely. High-energy Proton counts, however, appear to be slowly declining now. There is a daily slight chance of S1/Minor Proton storms or greater, should any further significant flares occur, increasing to a chance on Day 4 (27 Dec) as the larger, more complex regions on the facing-disc advance into more favourable western locations for connection with Earth. In the absence of any notable flares, slightly raised proton counts should ease towards typical background values in the coming days.

Radiation Storms Probability (Exceedance)	Level ($cm^{-2}sr^{-1}s^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	20	20	20	25
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and/or 50 MeV ≥ 10pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 5: Latest GOES18 High-energy Proton flux observations.



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High Energy Electrons (≥ 2MeV)

Current high energy electron flux is oscillating between moderate and diurnally high levels. This trend is likely to continue at GEO in the next few days, as solar wind pressure from CH01/- slowly starts to ease, with more extended periods of high flux considered likely in the absence of any potential CME arrival on Day 1 (24 Dec). The expected arrival of a CME on Day 2 (25 Dec), or perhaps early Day 3 (26 Dec), is more likely to temporarily suppress electron counts, before potentially increasing again by late Day 4 (27 Dec). There is a small likelihood that the onset from the fast-wind of CH02/+ could occur from Day 3 (26 Dec) onwards to further suppress electron flux, but this is considered unlikely to connect strongly with Earth.

Electron fluence is forecast to remain below the Active threshold on Day 1 and 4 (24 and 27 Dec), but with a likely exceedance on Days 2 and 3 (25 and 26 Dec). Given uncertain CME and fast-wind influence, the forecast carries lower than average confidence levels, although MOSWOC REFM output appears to give a reasonable steer for the upcoming days.

GEO Electron Environment	Level ($cm^{-2}sr^{-1}$ day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ 1×10^{8}	No	10	60	60	20
Very Active	≥ 2 MeV ≥ 1×10^{9}	No	1	1	1	1

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Figure 6: GOES16 >2MeV Electron Flux (above) and MOSWOC REFM forecast and Recurrence (below).

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